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TITLE Compositions and methods for manufacturing starch-based compositions

US Patent No. (1):

6168857Brief Summary Text (42):

Accordingly, a preferred method for forming the molding composition used to form the sheets of the present invention comprises mixing together water, fibers and the auxiliary polymer using high shear mixing to substantially homogeneously disperse the fibers and form an aqueous fibrous mixture. Thereafter, the unmodified starch granules, inorganic mineral filler, and other optional admixtures are blended into the aqueous fibrous mixture to form the molding composition. Additional water may also be added at this time. The molding composition is then formed into a sheet by passing the molding composition through at least one set of forming rollers heated to the thermal precipitation temperature of the auxiliary polymer. The molding composition may be directly fed between the forming rollers by means of an extruding apparatus, preferably by means of a "wig wag" system. Alternatively, the extruder can have a sheet-forming die. The auxiliary polymer acts to prevent the gelatinizing starch granules within the sheet from adhering to the rollers.

Drawing Description Text (6):

FIG. 2B shows a "wig wag" extruding system for feeding the molding composition between the forming rollers.

Detailed Description Text (65):

While it has been recognized by the present inventors that auxiliary polymers (e.g., Methocel) provide optimal performance when making sheets using extrusion and roller processes, auxiliary polymers have the disadvantage of being more expensive compared to the other components used to make the sheets. Starch is a good binder and much less costly than auxiliary polymers, but has the disadvantage of being very sticky or tacky when used as the sole organic binder in sheet forming processes, often causing the sheets to adhere to stick to the rollers, which makes mass production of sheets problematic.

Detailed Description Text (123):

A comprehensive production sequence used to manufacture the starch-bound sheets and films of the present invention, which can be formed into containers or other articles, is set forth in FIG. 1A, including the apparatus for carrying out the following manufacturing steps: (1) preparing and mixing the molding composition; (2) extruding the mixture into a sheet, strand or other shape through an appropriate die; (3) passing the extruded mixture through at least one pair of forming rollers in order to form a sheet of the desired thickness and; (4) passing the sheet between further sets of rollers that gelatinize the starch and remove at least part of the water from the mixture; (5) further drying the sheet by rolling it onto one or more larger diameter heated drying rollers; (6) optionally compacting the sheet while in a slightly moist condition in order to eliminate unwanted voids and increase the strength of the sheet; (7) optionally drying the sheet after it has been compacted; (8) optionally finishing the sheet by passing it between one or more pairs of finishing rollers; and (9) optionally rolling the substantially dried sheet onto a spool to form a roll which can be stored and used when needed. Each of these manufacturing steps is set forth more fully below.

Detailed Description Text (124):

As shown in FIG. 1B, the moldable mixture can alternatively be fed directly between the sheet-forming rollers. FIG. 2B depicts a "wig wag" extruding apparatus which rapidly feeds a bead or strand of material back and forth along the length of the sheet-forming rollers as another preferred process.

Detailed Description Text (125):

A second method suitable for most mix designs includes (1) mixing the moldable mixture in a kneader and then removing the air under a vacuum; (2) extruding and then cutting the mixture into individual units of an appropriate shape (such as a cylinder); (3) conveying the extruded units into a hopper; (4) passing the extruded units between a pair of self-feeding extruding rollers to form a sheet; and (5) optionally drying or otherwise finishing the sheet. The extrusion step aids in de-airing the moldable mixture and the individual extruded units provide a more uniform supply of the moldable mixture at the entrance of the extruding rollers.

Detailed Description Text (127):

The first step in the manufacture of sheets or films involves the formation of a suitable moldable mixture having the desired properties of workability and green strength, as well as strength, flexibility, toughness, and degradability of the final hardened sheet. Some of the properties considered to be generally desirable with regard to the moldable mixture are adequate workability, plastic-like qualities, and green strength for a given extrusion, rolling, and/or molding process. As set forth above, the level of water, organic binder, and (optionally) dispersant will determine the level of workability and extrudability of the mixture, as will the other components within the mixture, such as aggregates, fibers, plasticizers, air entraining agents, etc. However, no single component will completely determine the rheology and other properties of the moldable mixture. Rather, each of the components work together in an interrelated fashion.

Detailed Description Text (145):

It should also be understood that certain sheet forming processes, such as extrusion and rolling, will tend to orient the fibers in the direction of elongation of the mixture or sheet. This may be advantageous in order to maximize the tensile strength of the sheet in a certain direction. For example, where the sheet will be required to bend along a hinge, it is preferable for the fibers to be oriented in a way to more effectively bridge the two sides of the hinge by being oriented perpendicular to the fold line to reinforce the hinge in the sheet. In addition, it may be desirable to concentrate more of the fibers in the area of a hinge or where the sheet requires increased toughness and strength.

Detailed Description Text (163):

A double shaft sigma blade kneading mixer with an auger for extrusion is the preferred type of mixer. The mixer may be adjusted to have different RPMs and, therefore, different shear for different components. Typically, the moldable mixtures will be mixed for a maximum of about 10 minutes, and thereafter emptied from the mixer by extrusion for a maximum of about 3 minutes.

Detailed Description Text (169):

Once the moldable mixture has been properly blended, it is then transported to the sheet forming apparatus, which will typically comprise an extruder and a series of rollers. In some cases, an apparatus capable of both mixing and extruding the moldable mixture may be used in order to streamline the operation and minimize the coordination of the various components within the system. Reference is now made to FIG. 1A, which illustrates a currently preferred system for manufacturing sheets from a moldable mixture. The system includes a mixing apparatus 10, an auger extruder 20, a pair of sheet forming rollers 40, a first set of drying rollers 50, a pair of compaction rollers 60 (optional), a second set of drying rollers 70 (optional), a series of finishing rollers 80 (optional), and a spoiler 90 (optional).

Detailed Description Text (170):

In the first currently preferred sheet forming step, the moldable mixture is formed into a sheet by extruding the material through an appropriate extruder die and then passing the extruded material through at least one pair of reduction or forming rollers (FIG. 1A). Alternatively, the moldable mixture can be directly fed between the sheet-forming rollers as depicted in FIG. 1B. Depicted in FIG. 2B is a wig wag extruding system, which is yet another preferred embodiment of feeding the molding composition between the sheet-forming rollers.

Detailed Description Text (177):

The amount of pressure that is applied in order to extrude the moldable mixture will generally depend on the pressure needed to force the mixture through the die head, as well as the desired rate of extrusion. It should be understood that the rate of extrusion must be carefully controlled in order for the rate of sheet formation to correspond to the speed at which the sheet is subsequently passed through the rollers during the rolling step. If the rate of extrusion is too high, excess material will tend to build up behind the rollers, which will eventually cause clogging of the system. Conversely, if the rate of extrusion is too low, the rollers will tend to stretch the extruded sheet, which can result in a fractured or uneven structural matrix, or worse, breakage or tearing of the sheet. The latter can also result in, a complete breakdown of the continuous sheet forming process.

Detailed Description Text (178):

Because it will sometimes not be possible to control all of the variables that can affect the rate of extrusion, it may be preferable to have an integrated system of transducers which measure the rate of extrusion, or which can detect any buildup of excess material behind the rollers. This information can then be fed into a computer processor which can then send signals to the extruder in order to adjust the pressure and rate of extrusion in order to fine tune the overall system. As set forth below, a properly integrated system will also be capable of monitoring and adjusting the roller speed as well.

Detailed Description Text (179):

It should be understood that the pressure exerted on the moldable mixture during the extrusion process should not be so great as to crush or fracture the lightweight, lower strength aggregates if used. Crushing or otherwise destroying the structural integrity of lightweight aggregates containing a large amount of voids will decrease their insulating effect by eliminating the voids. Nevertheless, because perlite, exfoliated rock, or other such materials are relatively inexpensive, some level of crushing or fracturing of the aggregate particles is acceptable. Excessive pressure and shear can also cause the starch granules to prematurely gelatinize.

Detailed Description Text (180):

The properties imparted to the hardened sheets by the fibers can be increased by unidirectionally or bidirectionally orienting the fibers within the sheet. Depending on the shape of the extruder die head, the extrusion of the moldable mixture through the die head will tend to unidirectionally orient the individual fibers within the moldable mixture along the "Y" axis or machine direction of the extruded sheet. The rolling process, which is discussed in detail below, will further orient the fibers in the "NY" direction as the sheet is further elongated during the reduction process. In addition, by employing rollers having varying gap distances in the "Z" direction (such as conical rollers) some of the fibers can also be oriented in the "X" direction, i.e., along the width or cross-machine direction of the sheet. Thus, it is possible to create a sheet by extrusion, coupled with rolling, which will have bidirectionally oriented fibers.

Detailed Description Text (181):

In addition to the use of traditional extrusion methods, such as those set forth above, it may be preferable in some cases to either extrude individual mixture masses, which are conveyed to a hopper situated immediately above two horizontally oriented extruding rollers, or simply to convey the moldable mixture to the hopper. This eliminates the need to initially extrude the moldable mixture into a sheet before the rolling process. One conveyor method is an auger conveyor, which allows for variations in feed pressure of the moldable mixture through the rollers.

Detailed Description Text (182):

One of ordinary skill in the art will appreciate that the extrusion step need not formally employ the use of an "extruder" as the term is used in the art. The purpose of the extrusion step is to provide a continuous, well-regulated supply of the molding composition to the rollers. This may be achieved by other mechanisms known to those skilled in the art to effect the "extrusion" or flow of material through an appropriate opening. The force needed to cause a moldable mixture to flow may, for example, be supplied by gravity.

Detailed Description Text (183)

Reference should be made to FIG. 1B, which illustrates an alternative preferred embodiment in which the moldable mixture is fed directly from the mixer 10 to a pair of extruding reduction rollers 40, which converts the amorphous moldable mixture directly into a sheet without the use of an extruder die. As in the system illustrated in FIG.

1A, the sheet formed by forming rollers 40 is fed through a first set of drying rollers 50, a pair of compaction rollers 60 (optional), a second set of drying rollers 70 (optional), a series of finishing rollers 80 (optional), and is then wound onto a spooler 90 (optional). The forming rollers 40 will be heated to temperatures sufficient to cause initial film forming by the auxiliary polymer followed by gelatinization of the starch granules. They may also remove some of the water by evaporation. No significant amounts of water are removed in a liquid state using the preferred sheet-forming methods of the present invention.

Detailed Description Text (185):

As the thickness of the sheet is reduced upon passing through a pair of rollers, it will also elongate in the forward moving (or "Y") direction, otherwise known as the "machine direction." One consequence of sheet elongation is that the fibers will further be at least partially oriented or lined up in the machine direction. In this way, the reduction process in combination with the initial extrusion process can create a sheet having substantially unidirectionally oriented fibers in the machine direction. Increasing the speed of the reduction rollers, however, has been found to create a better randomization of fibers throughout the sheet.

Detailed Description Text (186):

Another way to maintain the random orientation of fibers within the sheet is to decrease the differential forming speed of the rollers. That is, where the moldable mixture is fed between the extruding rollers under lower pressures, the sudden increase in machine-direction velocity and accompanying shear as the mixture passes between the rollers will tend to orient the fibers in the machine direction. However, by increasing the pressure of the mixture as it is fed between the rollers it is possible to decrease the level of machine-direction shear, thereby resulting in a sheet with a more randomized fiber orientation.

Detailed Description Text (210):

In other embodiments, the finishing rollers can impart a desired texture, such as a meshed, checkered, or waffled surface. Alternatively, or in conjunction with any other finishing process, the sheets may be corrugated by means of corrugating rollers as shown in FIG. 7. If desired, rollers can be used to imprint the surface of the sheet with a logo or other design. Special rollers capable of imparting a water mark can be used alone or in conjunction with any of these other rollers. The extruding rollers, reduction rollers, or compaction rollers may contain means for producing a water mark by either producing a raised or depressed area within a sheet passing therethrough.

Detailed Description Text (231):

The coatings may be applied to the sheets using any coating means known in the art of manufacturing paper, paperboard, plastic, polystyrene, sheet metal, or other packaging materials, including blade, puddle, air-knife, printing, Dahlgren, gravure, and powder coating. Coatings may also be applied by spraying the sheet, article, or other object with any of the coating materials listed below or by dipping the sheet, article, or other object into a vat containing an appropriate coating material. Finally, coatings may be coextruded along with the sheet in order to integrate the coating process with the extrusion process.

Detailed Description Text (241):

It may sometimes be preferable to concentrate more fibers at the location where the score cut or perforation is made. This can be accomplished by co-extruding a second layer of molding material containing a higher fiber content at predetermined timed intervals to correspond with the location of the score cut or perforation. In addition, fibers can be placed on top of, or injected within, the sheet during the extrusion or rolling processes in order to achieve a higher fiber concentration at the desired location.

Other Reference Publication (22):

Robinson, Extrusion Defects. (No date).